cases the body is changed into a denser variety, whence may be inferred that the state taken by matter is in relation to the volume it is obliged to occupy under action of external forces. This (M. Spring points out) is merely the generalisation of a well-known fact. Some curious results are deduced from it. The researches described have important bearings on mineralogy and geology.

MR. R. CROWE of Liverpool communicates to the *British Journal of Photography* an account of some attempts to photograph a landscape by the aid of lightning-flashes. A gelatine plate, requiring by day an exposure of two seconds, was exposed from 10.15 p.m. to 10.45 p.m., during which time there were 120 brilliant flashes and about half as many minor ones. Most of these were in a horizontal direction, and five or six of then were imprinted on the negative. A perpendicular flash which struck a church-tower half a mile away was rendered with extraordinary sharpness and brilliancy. The surrounding objects, in spite of the long exposure, were but feebly impressed; whence Mr. Crowe argues that though the light of a flash of lightning is of a very actinic character, there still is not sufficient volume of light to illuminate a landscape or building to allow a successful photograph to be taken. Mr. Crowe further suggests that an attempt should be made to photograph, for scientific purposes of reference, the varied forms assumed by lightning at different times and in different countries.

GEOGRAPHICAL NOTES

NEWS has been received from Zanzibar that Capt. Carter and Mr. Cadenhead, of the Belgian Exploration Expedition, have been killed by the chief "Wrambo." This is probably the chief Mirambo, who formerly caused so much trouble to explorers between Zanzibar and Lake Tanganyika, but of whom Mr. Stanley gives so good a report in his last work. It was Capt. Carter who was so successful in the introduction of Indian elephants into Africa.

THE August number of the Geographical Society's *Proceedings* contains Mr. im Thurm's paper on his journey in British Guiana, already noticed in our columns, but the principal feature this month is of course the paper on Kuldja by Major F. C. H. Clarke, R.A., a well-known military writer on Eastern affairs. After a useful historical sketch, Major Clarke deals successively with the geography, orography, rivers, communications, towns, population, climate, vegetable products, and minerals of the region, and furnishes much interesting information, collected with evident care. This paper is followed by an account of M. Severtsoff's journey in Ferghana and the Pamir, from a translation by M. Alexis Lomonossoff, of the Russian Geographical Society. The geographical notes furnish information respecting the East African Expedition, the climate of Matabele-land, the recent observations of Dr. Matteucci in Kordofan, and Dr. Gerhard Rohlfs' account of the Jofra oasis. After notes on American Arctic expeditions and the position of the Crozet Islands, we have Mr. Whymper's account of his ascent of the famous Antisana mountain in South America, and lastly Mr. A. Forrest's own narrative of his journey through North-Western Australia. Two maps are given with the present number, one of British Guiana, which is very acceptable, and the other of the Kuldja district and the Russo-Chinese frontier in Turkistan.

WITH the August number of their *Herald* the Baptist Missionary Society publish a map of Equatorial Africa, which, though presumably not laying claim to scientific accuracy, is of interest as showing what an immense region can be reached by means of the River Congo and its affluents. The map is intended to illustrate the scheme which Mr. Arthington has sketched out for the application of his last munificent donation to the Society. The geographical part of this great task consists in the exploration of the Nkutu and Ikelemba Rivers, the two principal tributaries of the Congo from the south, after passing Stanley Pool, and the opening of a route towards Lake Albert, along the Mbura River, which enters the Congo above Stanley's Aruwimi.

M. C. E. DE UJFALVY left Paris in July to undertake a new and important journey in Central Asia. He goes in the first instance to Orenburg, and thence to Tashkend, where he hopes to arrive at the end of next month. He contemplates staying the winter at Samarkand, and will commence his explorations next spring. His programme is an extensive one, and embraces a considerable part of the Southern Pamir region. In the course of his labours he will visit the Upper Zarafshan valley, Karategin, Wakhan, Shignan, Badakshan, and probably Afghanistan. The return journey will, if possible, be made through Persia and the Caucasus.

NEWS has arrived in Paris that a French mission has reached Segon Sokkova and has been well received by King Ahmadan. M. Soleillet, who is on his way to Senegal, is not a member of this expedition, and will proceed by another route to the same city.

THE *Weimar Gazette* states that Dr. Gerhard Rholfs is about to set out for Abyssinia, accompanied by Dr. Stecker, who will attempt a new exploration in Central Africa.

IT is stated that a fifth Belgian Expedition is about to start for Africa, intended to reinforce the expedition on the Congo under Mr. Stanley. It will be commanded by Lieut. Braconnier.

THE August number of *Petermann's Mittheilungen* contains an exhaustive article by Dr. Behm on the Island of Rodriguez, accompanied by a very clear map. Bernhard v. Struve discusses the question of an inland trade-route through Siberia. An excellent hydrographical article, with a large-scale chart, on the Lower Weser from Bremen to Bremerhaven, is contributed by Oherbau-Director L. Franzius of Bremen. The results of the various East African International Expeditions are described. The researches of the Danish schooner *Ingolf* in the seas around Iceland in 1879 are described by H. Wiehmann.

THE London Missionary Society have received intelligence of the safe arrival of their new Tanganyika Expedition at Zanzibar on May 29. The party is composed of the Revs. A. J. Wookey and D. Williams, with Dr. Palmer as medical assistant. When the last mail left, an efficient leader and some of the head-men had already been engaged, and they hoped to start for the interior early in July.

THE Church Missionary Society are sending out further reinforcements for their Nyanza mission. The Rev. P. O'Flaherty, an able Oriental scholar, who was an interpreter on Lord Raglan's staff in the Crimean war, left for Zanzibar early in July, and will probably accompany the Waganda chiefs on their journey back to Lake Victoria. Mr. W. E. Taylor, of Hertford College, Oxford, who has been trained as a medical missionary, and Mr. A. J. Biddlecombe have, we believe, just started for East Africa, and will in the first instance join Mr. Copplestone at Uyui.

L'Exploration for August 5 contains some interesting extracts from the letters of Col. Prejevalsky, describing the difficulties he had to encounter in attempting to reach Lhassa, in which he was foiled. The intrepid Colonel has evidently succeeded in making considerable natural history collections.

THE STRUCTURE AND ORIGIN OF CORAL REEFS AND ISLANDS[1]

DARWIN'S THEORY.—During the voyage of the *Beagle* and subsequently, Mr. Darwin made a profound study of coral reefs, and has given a theory of their mode of formation which has since been universally accepted by scientific men.

Darwin's theory may be said to rest on two facts—the one physiological, and the other physical—the former, that those species of corals whose skeletons chiefly make up reefs cannot live in depths greater than from 20 to 30 fathoms; the latter, that the surface of the earth is continually undergoing slow elevation or subsidence.

The corals commence by growing up from the shallow waters surrounding an island, and form a fringing reef which is closely attached to the shore. The island slowly sinks, but the corals continually grow upwards, and keep the upper surface of the reef at a level with the waves of the ocean. When this has gone on for some time a wide navigable water channel is formed between the reef and the shores of the island, and we have a barrier reef. These processes have but to be continued some stages further, when the island will disappear beneath the ocean, and be replaced by an atoll with its lagoon where the island once stood.

According to this simple and beautiful theory, the fringing reef becomes a barrier reef, and the barrier reef an atoll by a continuous process of development.

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[1] Abstract of paper read at the Royal Society of Edinburgh by Mr. John Murray. (Published by permission of the Lords Commissioners of the Treasury.)

Object of the Present Paper.—Prof. Semper,[1] during his examination of the coral reefs in the Pelew group, experienced great difficulties in applying Darwin's theory. Similar difficulties presented themselves to the author in those coral-reef regions visited during the cruise of the *Challenger*.

The object of the present paper is to show, *first*, that, while it must be granted as generally true that reef-forming species of coral do not live at a depth greater than 30 or 40 fathoms, yet that there are other agencies at work in the tropical oceanic regions by which submarine elevations can be built up from very great depths so as to form a foundation for coral reefs; *second*, that while it must be granted that the surface of the earth has undergone many oscillations in recent geological times, yet that all the chief features of coral reefs and islands can be accounted for without calling in the aid of great and general subsidences.

Nature of Oceanic Islands and Submarine Elevations.—It is now known that, with scarcely an exception,[2] all oceanic islands other than coral atolls are of volcanic origin. Darwin, Dana, and others have noticed the close resemblance between atolls and ordinary islands in their manner of grouping as well as in their shapes. In a previous paper the author pointed out the wide distribution of volcanic *débris* over the bed of the ocean in tropical regions, and the almost total absence of minerals, such as quartz, which are characteristic of continental land.[3] There is every reason for believing that atolls are primarily situated on volcanic mountains, and not on submerged continental land, as is so often supposed.

The soundings of the *Tuscarora* and *Challenger* have made known numerous submarine elevations: mountains rising from the general level of the ocean's bed, at a depth of 2,500 or 3,000 fathoms, up to within a few hundred fathoms of the surface. Although now capped and flanked by deposits of Globigerina and Pteropod ooze, these mountains were most probably originally formed by volcanic eruptions. The deposits in deep water on either side of them were almost wholly made up of volcanic materials.

Volcanic mountains situated in the ocean basins, which during their formation had risen above the surface of the water, would assume a more or less sharp and pointed outline owing to the denuding action of the atmosphere and of the waves, and very extensive banks of the denuded materials would be formed around them. Some, like Graham's Island, might be wholly swept away, and only a bank with a few fathoms of water over it be left on the spot. In this way numerous foundations may have been prepared for barrier reefs and even atolls.

Those volcanoes which during their formation had not risen above the surface of the sea (and they were probably the most numerous) would assume a rounded and dome-like contour,[4] owing to the denser medium in which the eruptions had taken place, and the deposits which had been subsequently formed on their summits.

In order to clearly understand how a submarine mountain, say half a mile beneath the sea, can be built up sufficiently near the surface to form a foundation on which reef-forming corals might live, it is necessary to consider attentively the

Pelagic Fauna and Flora of Tropical Regions.—During the cruise of the *Challenger* much attention was paid to the subject. Every day while at sea tow-nets were dragged through the surface waters; and while dredging they were sent down to various depths beneath the surface. Everywhere life was most abundant in the surface and sub-surface waters. Almost every haul gave many calcareous, siliceous, and other Algæ; great numbers of Foraminifera and Radiolaria, Infusoria, Oceanic Hydrozoa, Medusæ, Annelids; vast numbers of microscopic and other Crustacea, Tunicates, Pelagic Gasteropods, Pteropods, Heteropods, Cephalopods, Fishes, and fish-eggs; larvæ of Echinoderms, and of many of the above creatures, &c.

Most of these organisms live from the surface down to about 100 fathoms.[5] In calm weather they swarm near the surface, but when it is rough they are to be found several fathoms beneath the waves. They are borne along in the great oceanic currents which are created by the winds, and meeting with coral reefs, they supply the corals on the outer edge of the reefs with abundant food. The reason why the windward side of a reef grows more vigorously appears to be this abundant supply of food, and not the more abundant supply of oxygen, as is generally stated. The *Challenger* researches showed that oxygen was particularly abundant in all depths inhabited by reef-forming corals.

When these surface animals die, either by coming in contact with colder water or from other causes, their shells and skeletons fall to the bottom, and carry down with them some organic matter which gives a supply of food to deep-sea animals. The majority of deep-sea animals live by eating the mud at the bottom.

An attempt was made to estimate the quantity of carbonate of lime in the form of calcareous Algæ, Foraminifera, Pteropods, Heteropods, Pelagic Gastropods, in the surface-waters. A tow-net, having a mouth 12½ inches in diameter, was dragged for as nearly as possible half a mile through the water. The shells collected were boiled in caustic potash, washed, and then weighed. The mean of four experiments gave 2·545 grammes. If these animals were as abundant in all the depth down to 100 fathoms as they were in the track followed by the tow-net, this would give over 16 tons of carbonate of lime in this form in a mass of the ocean one mile square by 100 fathoms.[1]

Bathymetrical Distribution of the Calcareous Shells and Skeletons of Surface Organisms.—Although these lime-secreting organisms are so abundant in tropical surface waters, their cast-off shells and skeletons are either wholly or partially absent from by far the greater part of the floor of the ocean. In depths greater than 3,000 fathoms we usually met with only a few shells of Pelagic Foraminifera of the larger and heavier kinds; a few hundred fathoms nearer the surface they became more numerous, and we got a few of the smaller kinds and some Coccoliths and Rhabdoliths. At about 1,900 or 1,800 fathoms a few shells of Pteropods and Heteropods are met with; and in all depths less than a mile we have a deposit in which the shell and skeletons of almost every surface organism is to be found. In the equatorial streams and calms the calcareous Algæ, Pelagic Foraminifera, Pteropods, and Heteropods are more abundant in the surface waters than elsewhere; and it is in these same regions that we found their dead shells at greater depths than in the deposits of other parts of the ocean. Another circumstance influences the bathymetrical distribution of these surface shells. When there is a complete and free oceanic circulation from the top to the bottom, these dead shells are found at greater depths in the deposits than where the circulation is cut off by submarine barriers.

The agent by which these shells are removed is, as Sir Wyville

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[1] *Zeitschr. für Wissen. Zoologie*, vol. xiii. p. 563.

[2] New Zealand, New Caledonia, and the Seychelles have primitive rocks, if these can be regarded as oceanic islands. Some of the islands between New Caledonia and Australia may have primitive rocks, and the atolls in these regions may be situated on foundations of this nature.

[3] *Proc.* Roy. Soc. Edin., 1876-77, p. 247.

[4] Scrope on "Volcanoes," chap. viii.

[5] The Challengeridæ, and many of the other members of Hæckel's new order *Phæodaria*, certainly live deeper, as we never got them in the tropics except when the net was sent down to a depth of 200 or 300 fathoms.

[1] Among the varieties of Foraminifera recognised by Mr. Brady in the *Challenger* collections, the following have a Pelagic habitat.

Palvinulina Menardii.
,, *canariensis.*
,, *crassa.*
,, *Micheliniana.*
,, *tumida.*
Pullenia obliquiloculata.
Sphærodina dehiscens.
Caudeina nitida.
Hastigerina Murrayi.
Hastigerina pelagica.
Orbulina universa.
Globigerina bulloides.
,, *æquilateralis.*
,, *sacculifera* (hirsuta).
,, *dubia.*
,, *rubra.*
,, *conglobata.*
,, *inflata.*

It is the dead shells of these Pelagic Foraminifera which chiefly make up the calcareous oozes of the deep sea. The living shells of all the above varieties swarm in the tropical and sub-tropical waters near the surface. It is especially in the region of the equatorial calms that the largest and thickest shelled specimens are found. As we go north or south into colder water they become smaller, and many varieties die out. In the surface-waters of the Arctic and Antarctic regions, only some dwarfed specimens of *Globigerina bulloides* are met with. The author is unable to agree with Dr. Carpenter and Mr. Brady in thinking that these Pelagic Foraminifera also live on the bottom. This question was made the subject of careful investigation during the cruise. The shells from the surface and from the bottom were compared at each locality, and it was found, by micrometric measurement, that surface specimens were as large and as thick-shelled as any average specimens from the soundings. It is quite unlikely that the same individuals should pass a part of their lives in the warm sunny surface-waters, at a temperature of from 70° to 80° F., and another part in the cold dark waters two or three miles beneath, at a temperature of 30° or 40° F. The geographical distribution of these Pelagic forms over the bottom coincides exactly with the distribution of the same forms on the surface, that is to say, both on the surface and on the bottom the distribution is ruled by surface-temperature. No specimens of these Pelagic varieties were ever obtained from the bottom with the shells filled and surrounded with sarcode. Whereas creeping and attached forms (like Truncatulina, Discorbina, Anomalina, and some Textulariæ) were taken in this condition in almost every dredge. These last-mentioned forms, which we know live on the bottom, have a distribution quite independent of surface-temperature.

Thomson suggested, carbonic acid. Analysis shows that carbonic acid is most abundant in sea-water, and especially so in deep water. Pteropod and Heteropod shells are very much larger than the Foraminifera, yet are very much thinner; and hence, for the quantity of lime contained in them, they present a much greater surface to the action of the sea-water. This seems to be the reason why all large and thin shells are first removed from the deposits with increasing depth, and not the fact that some shells are composed of arragonite and some of calcite, as has been suggested.

There is a continual struggle in the ocean with respect to the carbonate of lime. Life is continually secreting it and moulding it into many varied and beautiful forms. The carbonic acid of ocean-waters attacks these when life has lost its hold, reduces the lime to the form of a bicarbonate, and carries it away in solution. In all the greater depths of the ocean these surface shells are reduced to a bicarbonate either during their fall through the water or shortly after reaching the bottom.

In the shallower depths—on the tops of submarine elevations or volcanoes—the accumulation of the dead siliceous and calcareous shells is too rapid for the action of the sea-water to have much effect. Long before such a deposit reaches sufficiently near the surface to serve as a foundation for reef-forming corals, it is a bank on which flourish numerous species of Foraminifera, Sponges, Hydroids, deep-sea Corals, Annelids, Alcyonarians, Molluscs, Polyzoa, Echinoderms, &c. All these tend to fix and consolidate such a bank, and add their shells, spicules, and skeletons to the relatively rapid accumulating deposits. Eventually coral-forming species attach themselves to such banks, and then commences the formation of

Coral Atolls.—Mr. Darwin has pointed out that "reefs not to be distinguished from an atoll might be formed"[1] on submerged banks such as those here described. However, the improbability of so many submerged banks existing in the open ocean caused him to reject this mode of formation for atolls. As here stated, recent deep-sea investigations have shown that submerged banks are continually in process of formation in the tropical regions of the ocean, and it is in a high degree probable that the majority of atolls are seated on banks formed in this manner.

Mr. Darwin has also pointed out that the corals on the outer margin of a submerged bank would grow vigorously, whilst the growth of those on the central expanse would be checked by the sediment formed there, and by the small amount of food brought to them.[2] Very early in the history of such an atoll, and while yet several fathoms submerged, the corals situated on the central parts would be placed at a disadvantage, and this would become greater and greater as the coral plantations approached the surface. When the coral plantation was small there was a relatively large periphery for the supply of food to the inner parts, and also for the supply of sediment; and hence in small atolls the lagoon was very shallow, and was soon filled up. For the same reasons coral islands situated on long and narrow banks have no lagoons. An atoll one mile square has a periphery of four miles. In an atoll four miles square—the periphery increasing in arithmetical progression and the area as the square—we have for each square mile only a periphery of one mile over which food may pass to the interior, and from which sediment is supplied for filling up the lagoon.

With increasing size, then, the conditions become more and more favourable to the formation of lagoons, and as a consequence we have no large or moderate sized coral islands without lagoons. Tow-net experiments always showed very much less Pelagic life (food) in the lagoon waters than on the outer edge of the reef. The lagoon becomes less favourable for the growth of all the more massive kinds of coral as the outer edge of the reef reaches the surface, and cuts off the free supply of ocean-waters. Many species of corals die.[3] Much dead coral, coral rock, and sediment is exposed to the solvent action of the sea-water. Larger quantities of lime are carried away in solution as a bicarbonate from the lagoon than are secreted by the animals which can still live in it; the lagoon thus becomes widened and deepened.[4]

On the other hand a vigorous growth and secretion of lime takes place on the outer margins of the reef; and when the water outside becomes too deep for reef-forming corals to live, these still build seawards on a talus of their own *débris*:—the whole atoll expands somewhat after the manner of a fairy ring.

It is not necessary to call in disseverment of large atolls in order to explain the appearances presented in the Great Maldiva group of atolls.[1] The coral fields rising from very many parts of these extensive submarine banks form atolls. The marginal atolls have from the first the advantage of a better supply of food. They elongate in the direction of the margin of the bank where the water is shallower than to seaward. Many of these marginal atolls have coalesced, and as this growth and coalescence have continued, a large part of the food-supply has been cut off from the small atolls situated towards the interior of the bank. Ultimately a large atoll-like Suadiva atoll would be formed. The atolls in the interior would be perhaps wholly removed in solution, and the atoll-like character of small marginal but now coalesced atolls would be wholly or partially lost by the destruction of their inner sides.[2] A study of the charts shows all the stages in this mode of development.

In the case of the Lakadivh, Caroline, and Chagos archipelagos we have submarine banks at various stages of growth towards the surface, some too deep for reef-forming species of coral, others with coral plantations, but all submerged several fathoms, and scattered amongst these some of the oldest and most completely-formed atolls and coral islands. It is most difficult to conceive how these submerged banks could have been produced by subsidence, situated as they are in relation to each other and with respect to the perfectly-formed atolls, barrier or fringing reefs of the groups.

It is a much more natural view to regard these atolls and submerged banks as originally volcanoes reaching to various heights beneath the sea, and which have subsequently been built up to and towards the surface by accumulations of organic sediment and the growth of coral on their summits. It is a remarkable fact that in all coral atolls which have been raised several hundred feet above the sea, the base is generally described as composed of solid limestone, or "of various kinds of coral evidently deposited after life had become extinct."[3] This base is probably often made up of such a rock as that brought by the missionaries from New Ireland, and described by Prof. Liversidge,[4] as composed chiefly of Pelagic foraminifera, the same as those taken by the *Challenger* in the surface waters of the Pacific.

Microscopic sections of a rock taken from 50 feet below sea-level at Bermuda show that a deposition of carbonate of lime is going on. The small shells are filled with, and the broken pieces of shells and corals are cemented by, calcite. The wells in coral islands rise and fall with the tide, so that the whole atoll is filled like a sponge with sea-water. This water is very slowly interchanged, and by the solution of the smaller and thinner particles becomes saturated, and a deposition of lime follows. In this way we may explain the absence of many of the more delicate shells from some limestones.[5]

Barrier Reefs.—During the visit of the *Challenger* to Tahiti a careful examination was made of the reefs by dredging, sounding, &c., in a steam pinnace, both inside and outside the reefs. Lieutenant Swire, of the *Challenger*, made a careful trigonometrical survey of the profile of the outer reefs on six different lines; and while associated with him in this work the author was indebted to that officer for many valuable suggestions.

A ledge ran out from the edge of the reef to about 250 yards, where we got a depth of from 30 to 40 fathoms. It was covered with a most luxuriant growth of coral bosses and knobs.

Between 250 and 350 yards from the edge of the reef there was generally a very steep and irregular slope; about 100 fathoms was got at the latter distance, and the angles between these last-mentioned distances often exceeded 45 degrees. The talus here appeared to be composed of huge masses and heads of coral, which had been torn by the waves from the upper ledge and piled up on each other. They were now covered with living Sponges, Alcyonarians, Hydroids, Polyzoa, Foraminifera, &c.[1]

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[1] "Coral Reefs," p. 118. [2] "Coral Reefs," p. 134.

[3] There are no living corals or shells in some small lagoons, the waters of which become highly heated, and in some cases extremely saline.

[4] Complete little Serpula-atolls, with lagoons from 3 to 50 feet in diameter, and formed in this way without subsidence, were numerous along the shores of Bermuda.

[1] Mr. Darwin's application of his theory to this group—where the disseverment of large atolls is called in, and a destructive power attributed to oceanic currents, which it is very unlikely they can ever possess—has often been considered unsatisfactory.

[2] "In speaking of Bow Island, Belcher mentions the fact that several of its points had undergone material change, or were no longer the same when visited after the lapse of fourteen years. These remarks refer particularly to islets situated within the lagoon. I could myself quote many instances of the same description."—"Wilkes' Exploring Expedition," vol iv. p. 271.

[3] "U.S. Ex. Exp.," vol. iv. p. 269. [4] *Geol Mag.*, December, 1877.

[5] Fuchs, "Ueber die Entstehung der Aptychenkalke," *Sitzb. der k. Akad der Wissensch.*, 1877.

From 350 to 500 yards from the edge of the reef we had a slope with an angle of about 30°, and made up chiefly of coral sand. Beyond 500 yards the angle of the slope decreased till we had at a distance of a mile from the reef an angle of 6°, a depth of 590 fathoms, and a mud composed of volcanic and coral sand, Pteropods, Pelagic and other Foraminifera, Coccoliths, &c.

In the lagoon channel the reefs were found to be fringed with living coral, and to slope downwards and outwards for a few feet, and then plunge at once to a depth of 10 or 16 fathoms. Many portions of these inner reefs were overhanging, and at some places overhanging masses had recently fallen away. Everywhere much dead coral rock was exposed to the solvent action of the sea-water. The reefs of Tahiti are at some places fringing, at other places there is a boat passage within the reef, and at Papiete there is a large ship channel with islets within, and the outer edge of the reef is a mile distant from the shore. The island itself is surrounded with a belt of fertile low land, frequently three or four miles wide; this shows that the island has not in recent times undergone subsidence; there are indeed reasons for supposing it has recently been slightly elevated. Everything appears to show that the reefs have commenced close to the shore and have extended seawards, first on a foundation composed of the volcanic detritus of the island, and afterwards on a talus composed of coral *débris* and the shells and skeletons of surface organisms.[2]

The lagoon channel was subsequently slowly formed by the solvent action of the sea-water thrown over the reefs at each tide, and the islets in the lagoon channel are portions of the original reef still left standing. The reefs have extended outwards from the island and have been disintegrated and removed behind in the same way as the atoll has extended outwards after reaching the surface.

Where reefs rise quite to the surface, and are nearly continuous, we find relatively few coral patches and heads in the lagoons and lagoon channels. Where the outer reefs are much broken up, the coral growths in the lagoon are relatively abundant. Where the water was deep and the talus to be formed was great, the outward growth has been relatively slow,[3] and the disintegrating forces in the lagoons and lagoon channels gaining in the struggle, the reefs would become very narrow, and might indeed be broken up. This, however, would admit the oceanic waters and more food, and growth would again commence on the inner as well as the outer sides of the still remaining portions. In the great barrier reef of Australia, where the openings are numerous and wide, the reefs have a great width. Where the openings are few and neither wide nor deep (as in lat. 12° 30′) the reefs are very narrow and "steep to"—on their inner side.

At the Admiralty Islands, on the lagoon side of the islets on the barrier reefs, the trees were found overhanging the water, and in some cases the soil washed away from their roots. It is a common observation in atolls that the islets on the reefs are situated close to the lagoons. These facts point out the removal of matter which is going on in the lagoons and lagoon channels.

Elevation and Subsidence.—Mr. Darwin has given many reasons for believing that those islands and coasts which have fringing reefs had recently been elevated, or had long remained in a state of rest. Throughout the volcanic islands of the great ocean basins the evidence of recent elevations are everywhere conspicuous. Jukes has given most excellent reasons for believing that the coast of Australia fronted by the barrier reef, and even the barrier reef itself, have recently been elevated.[1] Dana and Couthouy have given a list of islands in almost every barrier reef and atoll region which have recently been elevated.[2]

This is what we should expect. Generally speaking, all the volcanic regions which we know have in the main been areas of elevation, and we should expect the same to hold good in those vast and permanent hollows of the earth which are occupied by the waters of the ocean. It must be remembered that probably all atolls were seated on submarine volcanoes. Areas of local depression are to be looked for in the ocean basins on either side of and between groups of volcanic islands and atolls, and not on the very site of these islands. This is what the deep-sea soundings show if they show any depression at all. Subsidence has been called in in order to account for the existence of lagoons and lagoon channels, and the narrow bands of reef which inclose these; but it has been shown that these were produced by quite other causes—by the vigorous growth of the corals where most nourishment was to be had, and their death solution and disintegration by the action of sea-water and currents[3] at those parts which cannot be, on account of their situation, sufficiently supplied with food.

All the chief and characteristic features of barrier reefs and atolls may indeed exist with slow elevation, for the removal of lime from the lagoons and the dead upper surface of the reefs by currents, and in solution by rain and sea-water, might keep pace with the upward movement.

The most recent charts of all coral reef regions have been examined, and it is found possible to explain all the phenomena by the principles here advanced; while on the subsidence theory it is most difficult to explain the appearances and structures met with in many groups; for instance, in the Fiji islands, where fringing reefs, barrier reefs, and atolls all occur in close proximity, and where all the other evidence seems to point to elevation, or at least a long period of rest. In instances like the Gambier group the reefs situated on the seaward side of the outer islands would grow more vigorously than those towards the interior; they would extend in the direction of the shallower water, and ultimately would form a continuous barrier around the whole group. The distinguishing feature of the views now advanced is that they do away with the great and general subsidences required by Darwin's theory,[4] and are in harmony with Dana's views of the great antiquity and permanence of the great ocean basin, which all recent deep-sea researches appear to support.

Summary.—It was shown (1) that foundations have been prepared for barrier reefs and atolls by the disintegration of volcanic islands, and by the building up of submarine volcanoes by the deposition on their summits of organic and other sediments.

(2) That the chief food of the corals consists of the abundant Pelagic life of the tropical regions, and the extensive solvent action of sea water is shown by the removal of the carbonate of lime-shells of these surface organisms from all the greater depths of the ocean.

(3) That when coral plantations build up from submarine banks they assume an atoll form, owing to the more abundant supply of food to the outer margins, and the removal of dead coral rock from the interior portions by currents and by the action of the carbonic acid dissolved in sea-water.

(4) That barrier reefs have built out from the shore on a foundation of volcanic *débris* or on a talus of coral blocks, coral sediment, and Pelagic shells, and the lagoon channel is formed in the same way as a lagoon.

(5) That it is not necessary to call in subsidence to explain any of the characteristic features of barrier reefs or atolls, and that all these features would exist alike in areas of slow elevation, of rest, or of slow subsidence.

In conclusion it was pointed out that all the causes here appealed to for an explanation of the structure of coral reefs are proximate, relatively well known, and continuous in their action.

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[1] This ledge and steep slope beyond where a depth of 30 or 40 fathoms was reached, was characteristic of a large number of atoll and barrier reefs, and seemed due to wave action. Experiments had been made with masses of broken coral, and it was found that these could (on account of their rough and jagged surface) be built up into a nearly perpendicular wall by letting them fall on each other. A talus formed in water deeper than 40 fathoms, where there was little, if any, motion, would be different from one formed on land. In the latter case the disintegrating forces at work always tended to set the talus in motion; in the former case everything tended to consolidate and to fix the blocks in the positions first assumed. A removal of lime in solution would take place from the blocks forming this steep slope, but except in very deep water this would not be sufficient to check the outward extension of the reef.

[2] A dredging in 155 fathoms, close to the barrier reef of Australia (between it and Raine Island), gave a coral sand, which was, I estimate, more than two-thirds made up of the shells of surface animals.

[3] Hence in barrier reefs, where the depth outside is very great, we find the reefs running closer to the shore than where the depth is less, and consequently the talus to be formed is smaller.

[1] "Voyage of the *Fly*," vol i p. 335.

[2] Dana's "Corals and Coral Islands," p. 345; Couthouy's "Remarks on Coral Formations," *Bost. Journ. Nat. Hist.* See also Stutchbury, *West of England Journal.*

[3] Very strong currents run out of the entrances into lagoons and lagoon channels, and when the tow-net was used in these entrances it showed that a large quantity of coral detritus was being carried seawards.

[4] "We may conclude that immense areas have subsided, to an amount sufficient to bury not only any formerly existing lofty table-land, but even the heights formed by fractured strata and erupted matter."—"Coral Reefs," p. 190.

The author expressed his indebtedness to all his colleagues, to Prof. Geikie, to the Hydrographer and officers of the hydrographic department, and in a special manner to Sir Wyville Thomson, under whose direction and advice all the observations had been conducted.

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THE JAMIN CANDLE

A NEW system in addition to those already prominent in the extensive field of electric lighting is shortly to be introduced into this country in the form of a candle devised by the well-known French electrician M. Jamin. This invention brings with it a considerable reputation, and how far this may be justified we shall probably soon have the opportunity of judging.

It has not yet had a trial in England, and until this is done we can only rely on the results of experiments, apparently of a not very exhaustive or conclusive character, which have taken place in Paris, and which must be accepted with a considerable amount of reservation.

The following description of the new candle is that given by M. Jamin himself in his paper to the French Academy of May 31, 1880:—

"I have had the honour to submit to the Academy during its sitting of March 17, 1879, the principle of a new electric burner.

"I have since succeeded in constructing a practical lamp, which I will describe. It rests on a slate base, which can be fixed into the globes or lanterns, according to the requirements of the decorations, and which supports at the base a gutter of copper, wide, but not very thick, in order to avoid shadows, and at the top is a gutter of soft iron, intended to be magnetised and to attract a movable armature or plate. The alternating current of a Gramme machine passes first through a wire of thin copper folded round the gutter some fifteen or twenty times, and which constitutes the directing circuit. In the middle of this frame and in the same plane are placed the candles or pairs of carbon rods between which the electric arc is to play. There are three, but a larger number can be inserted if the lighting is to be prolonged. Each carbon rod is inserted in a metal socket, in which they stand vertically, point downwards, and are retained in this position by means of a spring.

"The working offers no difficulties and demands no skill. There is no insulating material between the carbons. Those on the right are fixed and vertical; those on the left, hang freely from hinges; the tops of their supports are conected by a small bar, which gives them a movement in common; the armature is attached by a lever to this bar, which it pushes towards the left by its weight, which brings the carbons together until one of them touches its companion. It is to be remarked that the contact will only be made in one of the candles, the longest, or the one whose points hang nearest together; that one will be lighted.

"The electric current, after having traversed the directing circuit, arrives simultaneously at the movable carbons, and can return indiscriminately by the three fixed carbons; it passes between those which touch, and lights them. Immediately the magnetism is made the armature is attracted, the three couples of carbons spring apart at the same time, two remaining cold, and the arc being established in the third. As long as there is any matter to burn it continues maintained at the points by the action of the directing current, and necessarily returning to it if any foreign cause should drive it away. When the current stops the armature falls back, and the contact is re-established; if it passes through again, the carbons are relighted, and spring apart as at first. Thus the lighting is automatic, instantaneous, and renewable at will.

"When the first candle is consumed, another must succeed it. For this purpose the left carbon-holder, which remained fixed, is jointed at the top and can be displaced, not in the plane of the frame, but perpendicularly. It is pushed by a spring, R, which tends to force it away, but it is kept vertical by a wire, B, bent round like a hook at its end, and which slides tightly in a receptacle where a spring presses it. When the combustion of the candle has brought the arc up to this point, the wire is melted, the carbon-holder is released, the two carbons spring suddenly apart, and the arc is extinguished, but immediately relights in the neighbouring candle. The change is so rapid that the action is hardly perceptible, and the other lamps in the same circuit are not at all affected.

"Besides, it must be remarked that this substitution of a fresh candle for the one consumed only happens every two hours, that the wire is only melted at its extremity, that it is sufficient to cut off the point to bend it again and to draw it a little further from its receptacle, when new carbons are to be inserted, and that it serves for a great number of times. One of the greatest inconveniences of electric lighting is the possible sudden extinction of one of the lamps, which immediately causes that of the other candles in the same circuit, although they may be in good condition. Ours are very little subject to this danger, but it must, however, be foreseen and remedied. For this purpose one of my pupils has devised a system, the description of which would be too long. Its effect is (1) to open, at the moment of accident, a secondary circuit, which continues the current across the faulty candle; (2) to replace the extinguished lamp by an equal resistance, which leaves the others in the condition in which they were at first.

"This addition is very important, as it permits of our lighting many or few candles without changing their brilliancy.

"To sum up, our lamp contains many essential qualities. It lights and relights itself as often as required; it only requires one circuit for all the neighbouring candles; it replaces automatically those which are entirely consumed, by new carbons; it employs no insulating material which might alter the colour of the flame; and it requires no preliminary preparation of the carbons, which considerably diminishes the expense. If at first it underwent, like all others, variations of brilliancy that were owing, not to the construction, but to the defective preparation of the carbons, these variations have disappeared since, thanks to M. Carré, to whom so much is already due, and who has just given to his carbons the necessary solidity."

In the summer of 1878 the writer, in conjunction with Mr. McEniry, carried out a series of experiments with various forms of electric candles for Mr. Robert Sabine; the result is embodied in his provisional specification of November 27, 1878, part of which runs as follows:—

"My third improvement in regulating the distance between the carbon electrodes of a regulator or lamp consists in taking advantage of the well-known fact that parallel conductors attract or repel each other according as the currents in them go in the same or in opposite directions. For this purpose I place the carbons vertically side by side, one of them being fixed and the other balanced over a fulcrum or centre. The frames carrying the two carbons form portions of the common electric circuit in such a way that when the current circulates the parallel portions of the balanced frame (which carries the movable carbon) are deflected and the carbons separated. The degree of deflection of the flame depending upon the current, it follows that, should from any cause the electromotive force in the circuit increase, the frame is thereby deflected more, and the electric arc is correspondingly increased in length, which reduces the current again and maintains the light more steadily than when the carbons are placed immovably side by side without any such adjustment."

It is presumed by the writer that M. Jamin's paper to the French Academy of March 17, 1879, explaining the principle of his new candle, was the first public notice of it, and it will be therefore clearly seen that the part of the apparatus which he claims as particularly his own, viz., the directing frame, is in reality due to Mr. Sabine, and that while giving every credit to M. Jamin for independence of thought, it is only in common justice to Mr. Sabine that he should receive the merit of an idea which, in the words of a very flattering notice of the origin of Jamin's candle in a recent number of *La Lumière Electrique*, constitutes an elegant application of Ampère's laws.

Mr. Sabine's arrangement is also of a more simple nature than the candle just described, for it not only regulates the arc but separates the carbons without the aid of magnetism, and this could be as easily accomplished for a combination of three candles as for one.

It is probable that this latter candle was never constructed beyond the experimental stage, but that it could be put into a very simple and practical form is obvious.

Having thus shown that the two systems are identical, we will turn our attention to the consideration of the claims of this particular form of candle as now perfected and brought forward by M. Jamin.

It is questionable whether the surrounding frame of wire is as efficacious as we are led to believe, but that it exerts a certain influence on the electric arc is beyond doubt; but whether this favours the light or acts detrimentally by blowing and expanding the arc remains to be proved. Again, the fact of burning an